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MARINE PHYSICAL LABORATORY OF THE
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PRICING DISTRIBUTIONS FOR SUBMERGED PRESSURE HULLS

Victor C. Anderson and H. P. Rumble

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13 ABSTRACT

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Prices for fabrication of steel pressure hulls suitable for submergence to several thousand feet were solicited from several hundred manufacturers. The information submitted by the companies responding is presented without identification. The mean value of the price and of the unit price is shown for each of seven alternative designs of pressure hull.

ACKNOWLEDGMENT

The cooperation of the thirty respondents in furnishing data and in permitting this analysis of the price information submitted is appreciated. This paper represents results of research sponsored by the Office of Naval Research and Advanced Research Projects Agency.

INTRODUCTION

In the fall of 1971 this Laboratory initiated an experimental investigation of the acoustic background in the ocean. During the preliminary design of the experiment a requirement arose for cylindrical vessels capable of resisting the external sea pressure to a submergence depth of several thousand feet to be used both to house electronic instrumentation and to provide several tons of buoyancy. Selection of materials and hull design obviously would be predicated primarily on cost factors and so, as a guide to design, we turned to industry.

A preliminary sketch design, Figure 1, was prepared and sent to about 375 companies listed in Thomas Register as being in the business of manufacturing pressure tanks with a request, Appendix A, for "ball park" estimates of the price of each of seven alternatives shown on Figure 1. It was hoped that the data in the replies would be helpful in determining the relative merit of the seven alternatives from the cost standpoint.

A total of thirty replies containing price data were received, but coincidentally the financial support of the project was greatly curtailed, forcing a deferment in the procurement. Inasmuch as these responses were valuable in themselves, it was decided to analyze the price data received and publish the results. Each of the thirty companies concerned gave permission to use the data furnished in the proposed analysis and expressed an interest in receiving a copy of the results.

DATA BASE

For ready reference the identification of the seven alternatives of Figure 1 is summarized in Table 1.

Table 2 shows the data received. Where necessary, the data has been converted in order to

put all prices on a uniform basis. In those cases in which respondents furnished an estimated weight, that weight was used to calculate unit price (dollars per pound). Where no estimated weight was furnished, unit price was based on MPL-estimated weight, which happens to be lower than any weight furnished by the respondents. One respondent gave unit price rather than a total price. His total price was calculated using MPL weight and his unit price. In each instance in Table 2 values supplied by MPL and values calculated by MPL are indicated by being included in parentheses.

Three of the respondents furnished price delivered in San Diego, with no indication of the amount included for transportation. These prices were adjusted to eliminate the cost of transportation based on information furnished by the local railroad freight office. The resulting total manufacturing price figures are enclosed in double parentheses.

For each alternative, the data are arranged in Table 2 in ascending order of total price.

ANALYSIS OF THE DATA

Figures 2a and 2b show a comparison of the fit of the data to a line when cumulative distributions are plotted on linear and on logarithmic probability paper. By visual inspection the data can be seen to fit a log-normal distribution because more of the points lie close to a straight line on the log paper.

For each alternative the values of total price and unit price from Table 2 were plotted on log probability paper, Figures 3 through 16. The mean value was determined graphically by fitting a line to the data points in the middle portion of the range, rejecting the points at each end. The mean of the equivalent log-normal distribution is just the value at 50% probability. Using the actual data for all points, the mean and the standard deviation were calculated. Table 3 summarizes the results of these analyses.

To demonstrate the close agreement in the spread of the data among the seven alternatives, Figures 17 and 18 were prepared by drawing the normalized probability lines of all the alternatives with a mean value of 1.0.

DISCUSSION OF RESULTS

The wide spread in the prices furnished was surprising. Several factors can be listed as probably accounting for the spread. The MPL request, Appendix 1, called for "ball park" estimates only. This may have led some respondents to spend very little time on the estimate. The specifications were incomplete in that construction code requirements, testing program, sandblasting and painting were not mentioned. Some respondents included some or all of these items while others did not. A possible lack of familiarity with work of the type being considered may have caused an abnormal price deviation for some respondents which would not have occurred in a carefully prepared competitive bid.

The variation in weight estimates, highest being some 35% above the lowest, was also surprising. We did not request a weight estimate and it is assumed very little time was spent by the respondents in working up weight estimates. More than half provided no weight information.

CONCLUSIONS

The original intent was to ascertain the cost penalty, if any, in going to HY 100 material instead of HY 80 material. The latter has been used extensively and the fabrication procedures are well known. The HY 100, on the other hand, has been used much less and requires more care during fabrication. Structures built of HY 100 have the advantage of being lighter in weight for a given application.

The information furnished is not conclusive although the indications are that HY 100 may be slightly less expensive than HY 80.

Another aim was to determine the cost advantage of an unstiffened cylinder over a stiffened cylinder. Comparison of the mean values of the equivalent log-normal distributions for total price indicate only about a 15% advantage of the stiffened cylinder over the other. The price per pound for the unstiffened cylinder, on the other hand, is much less, due primarily to its much greater weight.

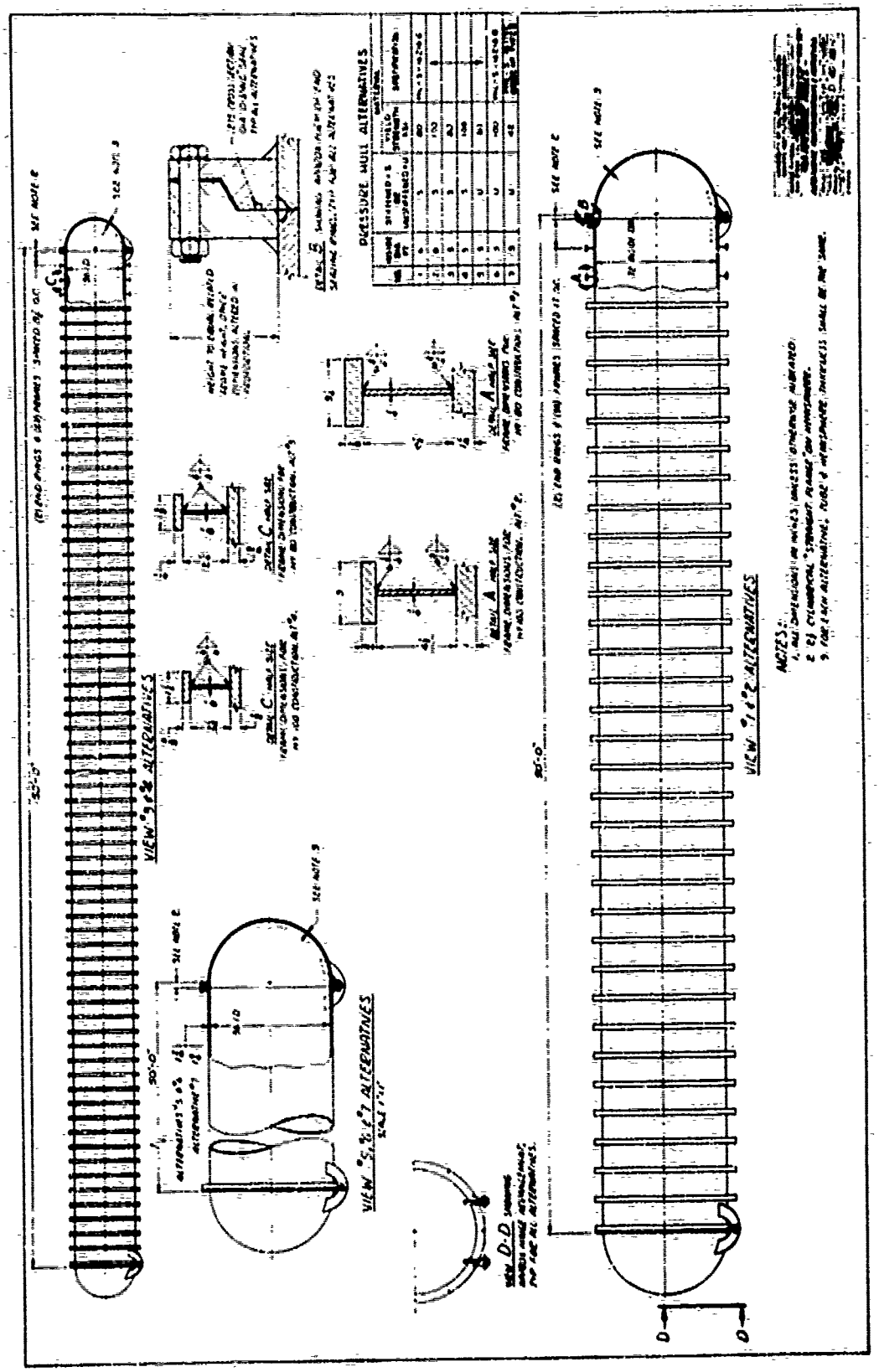


Fig. 1. ADA pressure hulls – alternative configurations and materials.

TABLE 1. IDENTIFICATION OF ALTERNATIVES

Alternative	Diameter (feet)	Stiffened or Unstiffened	Material
1	6	S	HY 80
2	6	S	HY 100
3	3	S	HY 80
4	3	S	HY 100
5	3	U	HY 80
6	3	U	HY 100
7	3	U	HTS (42,000 psi yield)

TABLE 2. PRICE AND WEIGHT DATA

Alternative 1			Alternative 2		
Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)	Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)
43,000	60,000	(0.72)	42,000	57,000	(0.74)
43,690	61,920	(0.71)	44,434	57,674	(0.77)
((48,225))	(59,780)	(0.81)	((46,830))	(55,619)	(0.84)
50,000	(59,780)	(0.84)	48,500	(55,619)	(0.86)
53,000	(59,780)	(0.89)	53,800	(55,619)	(0.97)
56,312	68,239	(0.83)	54,406	62,739	(0.87)
57,150	62,750	(0.91)	55,000	57,890	(0.95)
60,420	(59,780)	(1.01)	58,900	(55,619)	(1.06)
66,605	82,210	(0.81)	64,555	78,111	(0.83)
((66,879))	66,774	(1.00)	((64,581))	62,427	(1.04)
((74,952))	71,630	(1.05)	((67,663))	67,136	(1.01)
77,973	(59,780)	(1.30)	75,000	56,000	(1.34)
80,000	62,000	(1.29)	79,000	57,000	(1.39)
81,666	(59,780)	(1.37)	79,690	(55,619)	(1.43)
84,000	(59,780)	(1.40)	80,006	(55,619)	(1.44)
85,000	65,000	(1.31)	89,000	(55,619)	(1.60)
87,295	(59,780)	(1.46)	90,000	60,000	(1.50)
99,200	74,000	(1.34)	92,000	(55,619)	(1.66)
105,000	(59,780)	(1.76)	99,500	72,500	(1.38)
108,960	(59,780)	(1.82)	102,480	(55,619)	(1.85)
110,000	(59,780)	(1.84)	105,000	(55,619)	(1.89)
110,500	66,000	(1.67)	106,000	(55,619)	(1.91)
112,377	69,128	(1.62)	109,837	64,250	(1.71)
120,000	(59,780)	(2.01)	(114,019)	(55,619)	2.05
(122,549)	(59,780)	2.05	118,000	62,000	(1.91)
125,980	61,600	(2.04)	121,200	(55,619)	(2.18)
132,237	(59,780)	(2.22)	142,739	(55,619)	(2.56)
162,168	(59,780)	(2.71)	167,324	(55,619)	(3.01)
334,049	(59,780)	(5.59)	318,037	(55,619)	(5.73)

TABLE 2. PRICE AND WEIGHT DATA
(Continued)

Alternative 3			Alternative 4		
Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)	Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)
(,796))	(14,707)	(1.34)	19,240	14,344	(1.34)
,340	(14,707)	(1.38)	19,400	(12,980)	(1.50)
,390	16,063	(1.32)	((19,468))	(12,980)	(1.50)
,500	(14,707)	(1.49)	21,400	(12,980)	(1.65)
,000	17,067	(1.30)	22,000	16,000	(1.38)
,000	(14,707)	(1.56)	22,554	19,619	(1.15)
23,490	21,111	(1.08)	23,000	(12,980)	(1.77)
((24,489))	18,863	(1.30)	((24,281))	18,148	(1.38)
27,375	15,800	(1.77)	27,650	14,100	(1.96)
30,915	27,830	(1.11)	(29,265)	(12,980)	2.25
33,000	(14,707)	(2.24)	32,000	(12,980)	(2.46)
(33,091)	(14,707)	2.25	((32,254))	16,800	(1.92)
34,000	16,500	(2.06)	33,000	15,000	(2.20)
((34,719))	18,513	(1.88)	33,458	32,935	(1.02)
35,420	(14,707)	(2.40)	34,890	(12,980)	(2.69)
38,000	(14,707)	(2.58)	37,600	18,500	(2.09)
40,000	(14,707)	(2.72)	40,000	(12,980)	(3.08)
42,500	19,500	(2.18)	42,000	(12,980)	(3.24)
44,982	(14,707)	(3.06)	42,720	(12,980)	(3.29)
46,469	17,067	(2.72)	43,379	(12,980)	(3.34)
46,920	(14,707)	(3.19)	45,394	15,407	(2.94)
48,925	(14,707)	(3.32)	48,425	(12,980)	(3.73)
49,606	(14,707)	(3.37)	51,950	(12,980)	(4.00)
54,300	16,300	(3.33)	57,000	24,000	(2.38)
55,000	25,000	(2.20)	67,000	(12,980)	(5.16)
68,000	(14,707)	(4.62)	167,172	(12,980)	(12.88)
91,579	(14,707)	(6.22)			
225,401	(14,707)	(15.3)			

TABLE 2. PRICE AND WEIGHT DATA

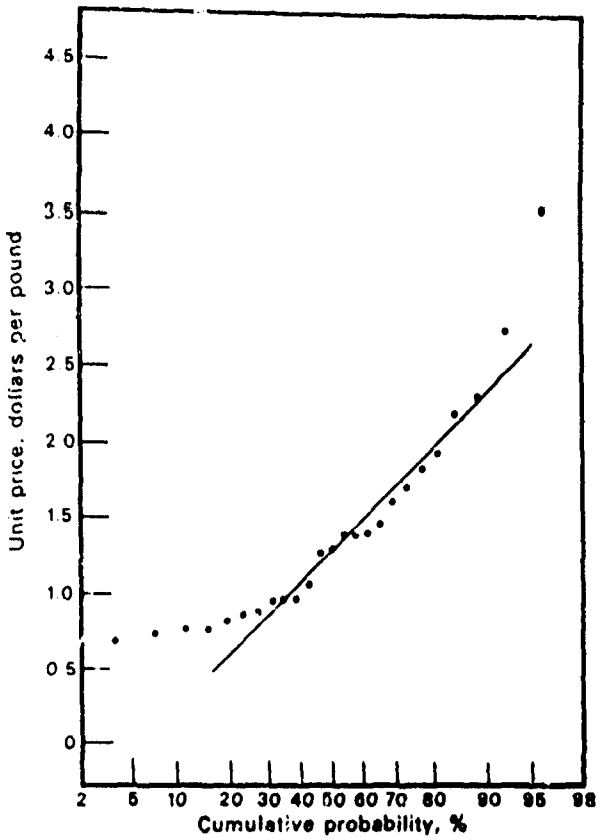
(Continued)

Alternative 5			Alternative 6		
Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)	Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)
((20,715))	(31,046)	(0.67)	((21,438))	(31,046)	(0.69)
22,800	(31,046)	(0.73)	23,600	(31,046)	(0.76)
23,500	33,000	(0.71)	24,000	33,000	(0.73)
27,375	36,577	(0.75)	27,000	(31,046)	(0.87)
28,000	(31,046)	(0.90)	28,072	36,577	(0.77)
((28,820))	36,160	(0.80)	((29,392))	36,160	(0.81)
((29,668))	35,469	(0.84)	((30,366))	35,465	(0.86)
29,875	32,150	(0.93)	30,450	32,150	(0.95)
31,672	32,765	(0.97)	31,672	32,765	(0.97)
32,050	(31,046)	(1.03)	33,000	34,000	(0.97)
32,500	34,000	(0.96)	33,300	(31,046)	(1.07)
34,000	(31,046)	(1.10)	43,000	(31,046)	(1.39)
41,880	(31,046)	(1.35)	43,150	34,200	(1.26)
42,500	34,200	(1.25)	43,541	(31,046)	(1.40)
43,000	(31,046)	(1.39)	45,000	35,000	(1.29)
44,000	35,000	(1.26)	45,210	(31,046)	(1.46)
44,000	(31,046)	(1.42)	46,373	33,388	(1.39)
45,860	33,388	(1.37)	50,000	(31,046)	(1.61)
(52,778)	(31,046)	1.70	(52,778)	(31,046)	1.70
55,000	(31,046)	(1.77)	57,000	(31,046)	(1.84)
57,000	(31,046)	(1.84)	60,000	(31,046)	(1.93)
65,748	(31,046)	(2.12)	67,948	(31,046)	(2.19)
67,560	(31,046)	(2.18)	71,400	(31,046)	(2.30)
80,877	(31,046)	(2.60)	84,793	(31,046)	(2.73)
111,614	(31,046)	(3.60)	109,985	(31,046)	(3.54)

TABLE 2. PRICE AND WEIGHT DATA

(Continued)

Alternative 7			Alternative		
Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)	Total Price (Dollars)	Weight (Pounds)	Unit Price (Dollars/Lb)
19,000	(38,047)	(0.50)			
((20,278))	(38,047)	(0.53)			
22,100	(38,047)	(0.60)			
22,374	42,949	(0.52)			
((23,111))	43,568	(0.53)			
25,000	40,200	(0.62)			
25,000	(38,047)	(0.66)			
((25,019))	45,051	(0.56)			
25,200	(38,047)	(0.66)			
25,450	39,100	(0.65)			
26,000	40,000	(0.65)			
26,700	40,000	(0.67)			
34,890	39,178	(0.89)			
34,925	43,400	(0.83)			
35,000	(38,047)	(1.13)			
36,000	43,000	(0.84)			
36,110	(38,047)	(0.95)			
38,374	(38,047)	(1.01)			
39,900	41,000	(0.97)			
43,617	40,683	(1.07)			
47,000	(38,047)	(1.24)			
(47,558)	(38,047)	1.25			
50,000	(38,047)	(1.32)			
56,565	(38,047)	(1.49)			
66,120	(38,047)	(1.74)			
69,721	(38,047)	(1.83)			
119,050	(38,047)	(3.14)			



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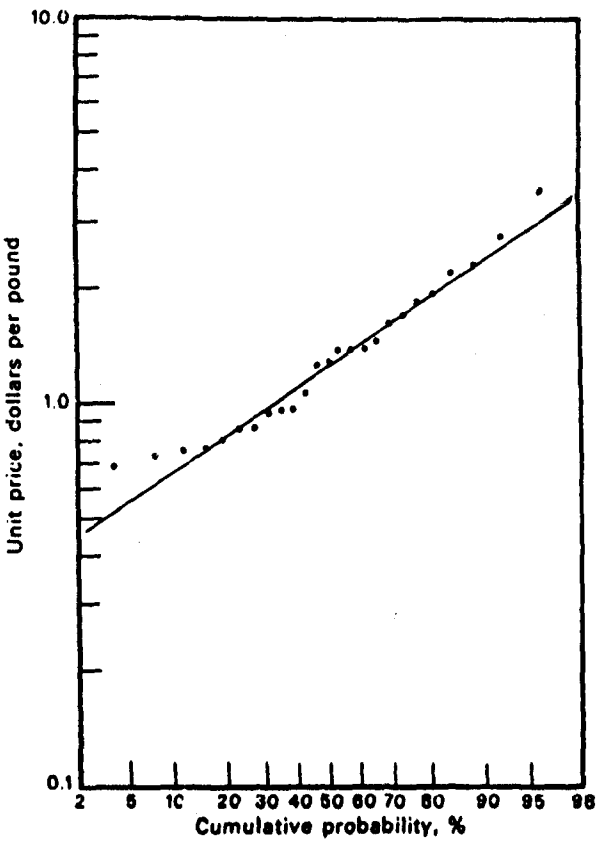

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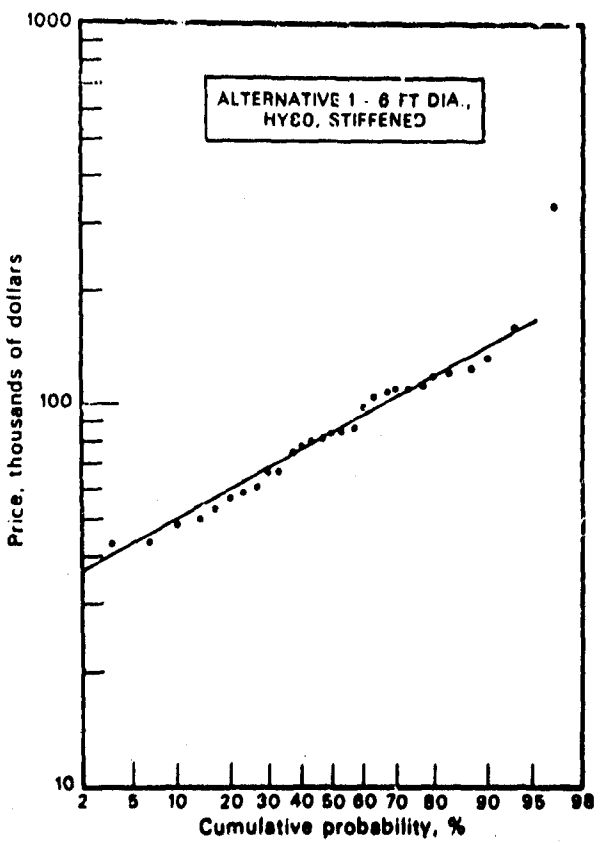

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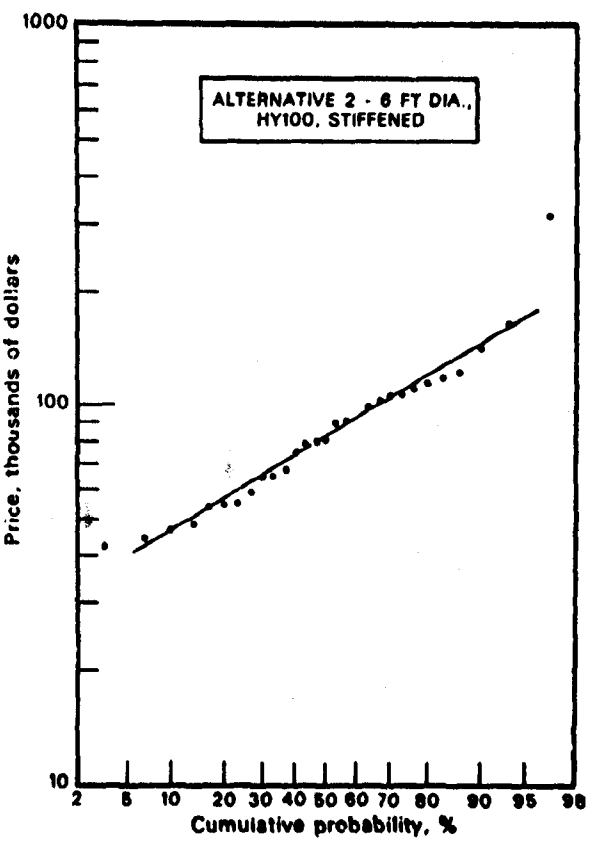

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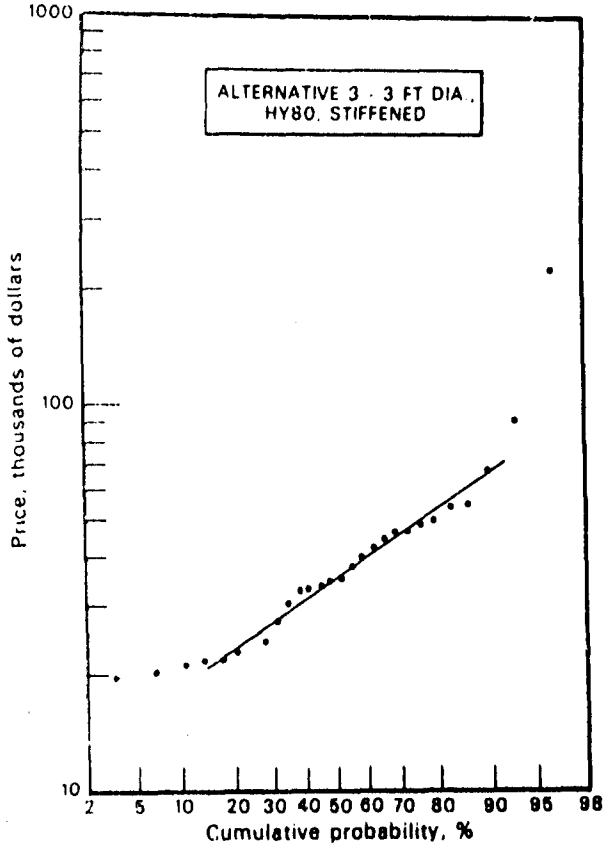

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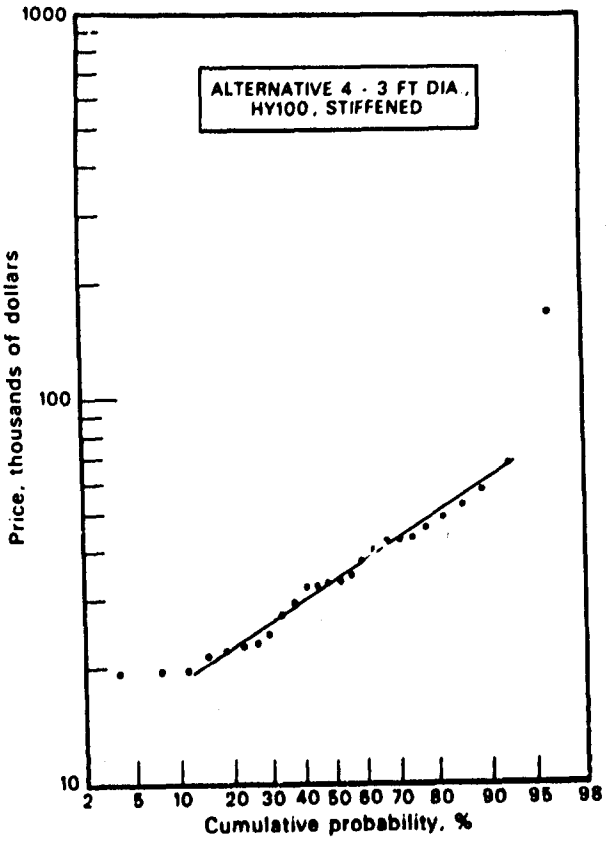

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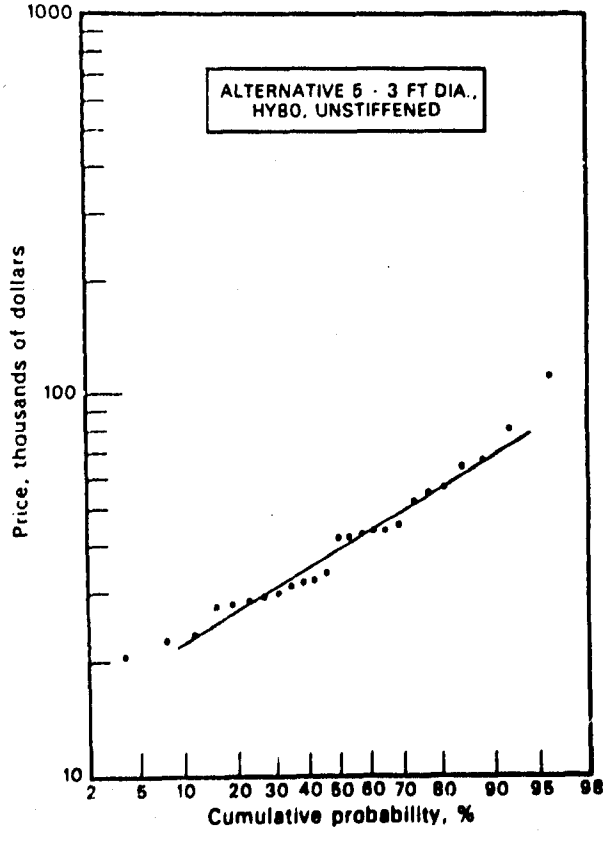

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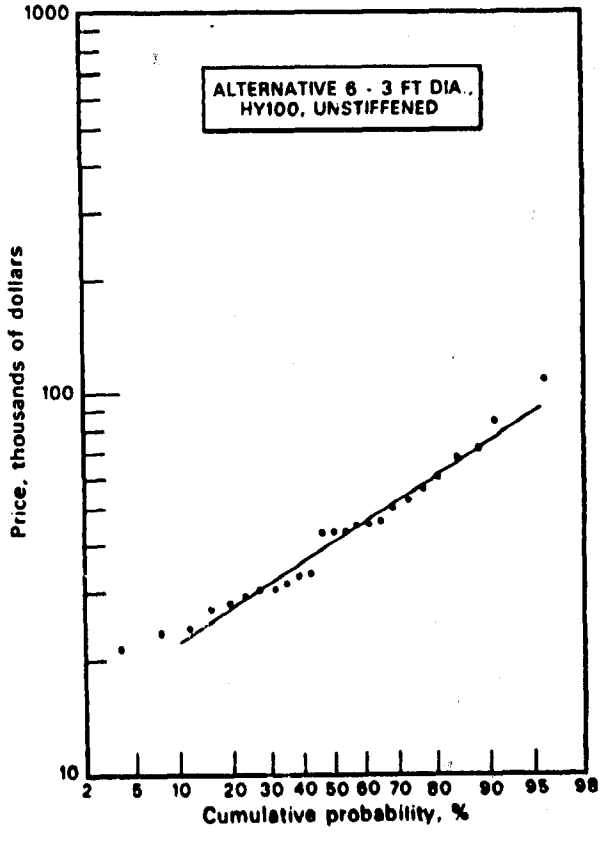

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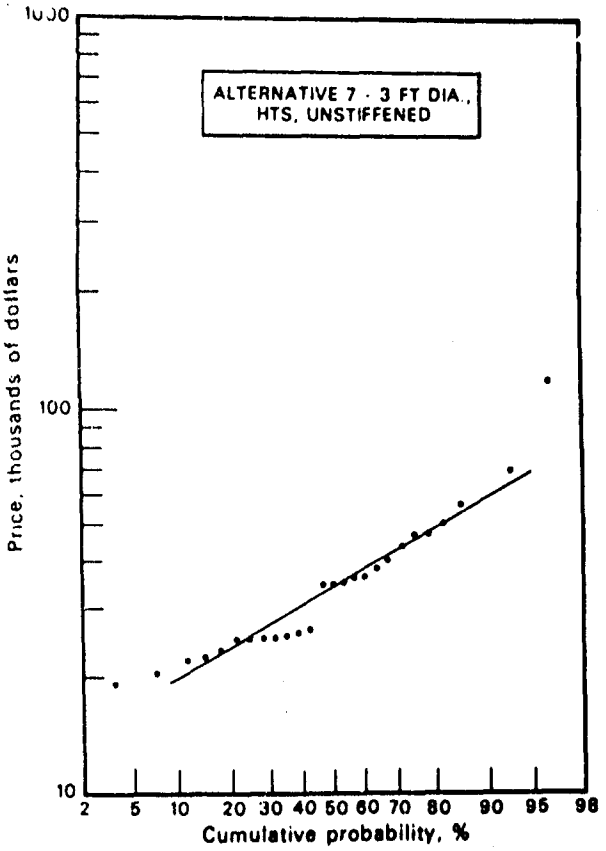

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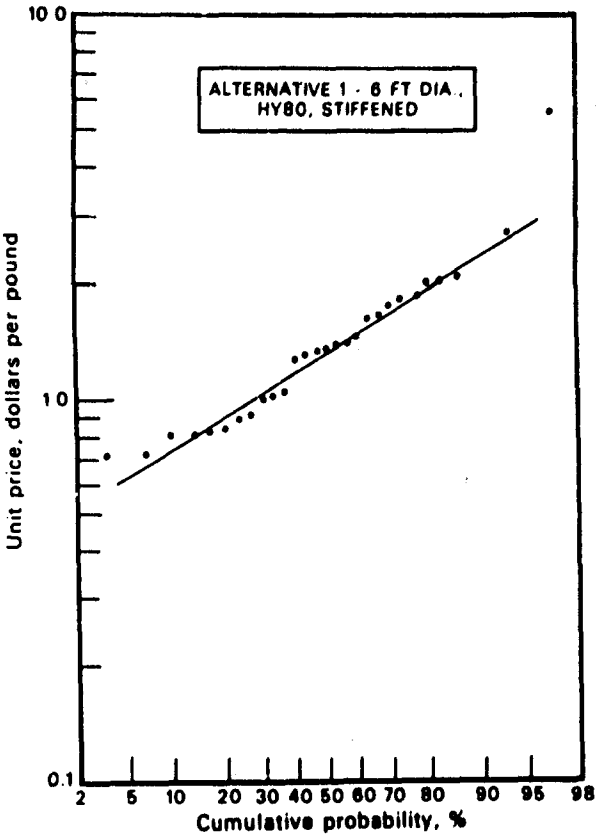

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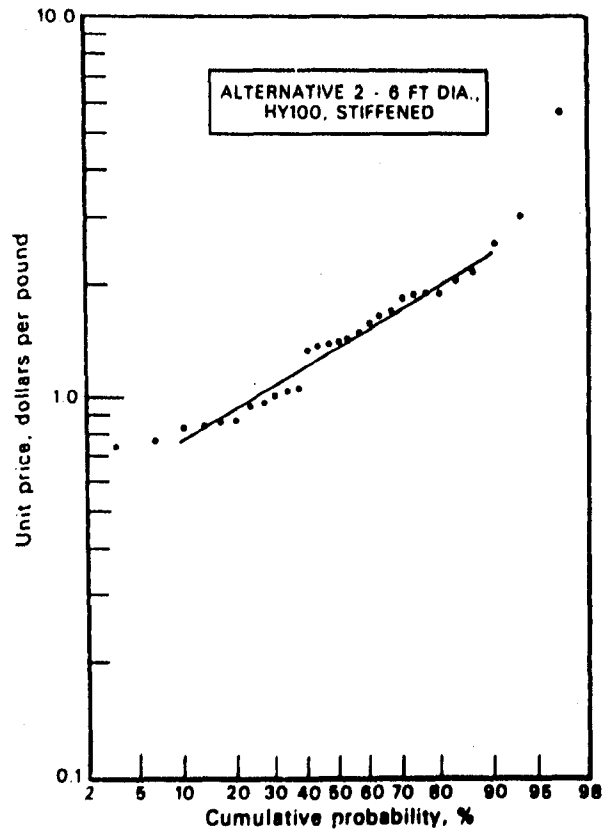

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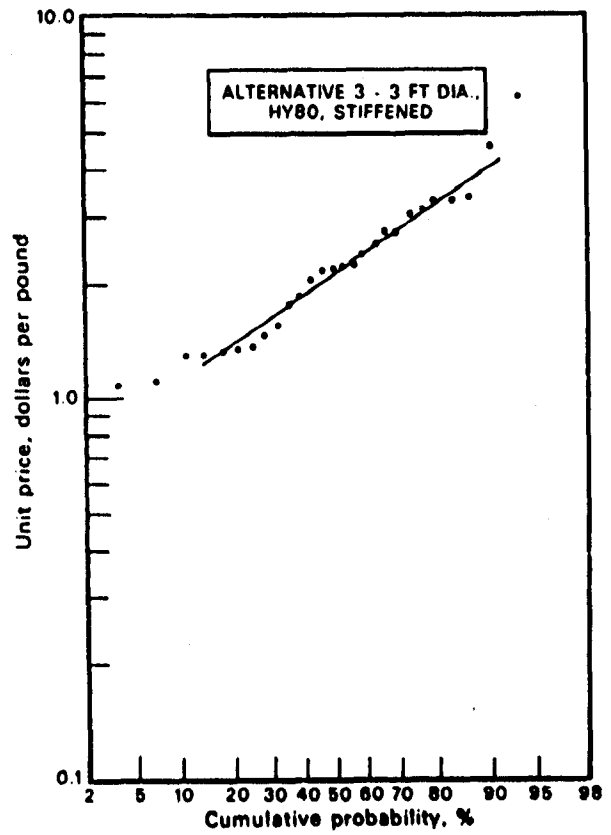

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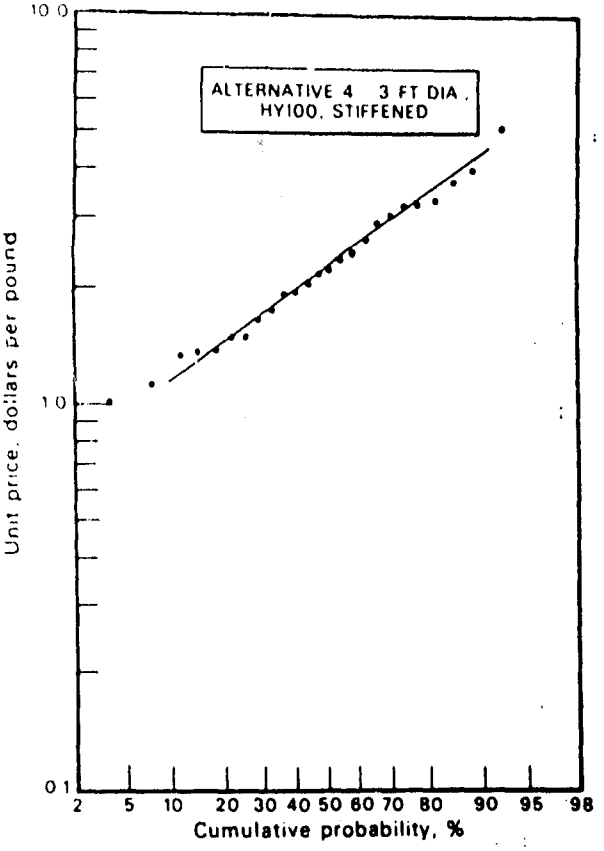

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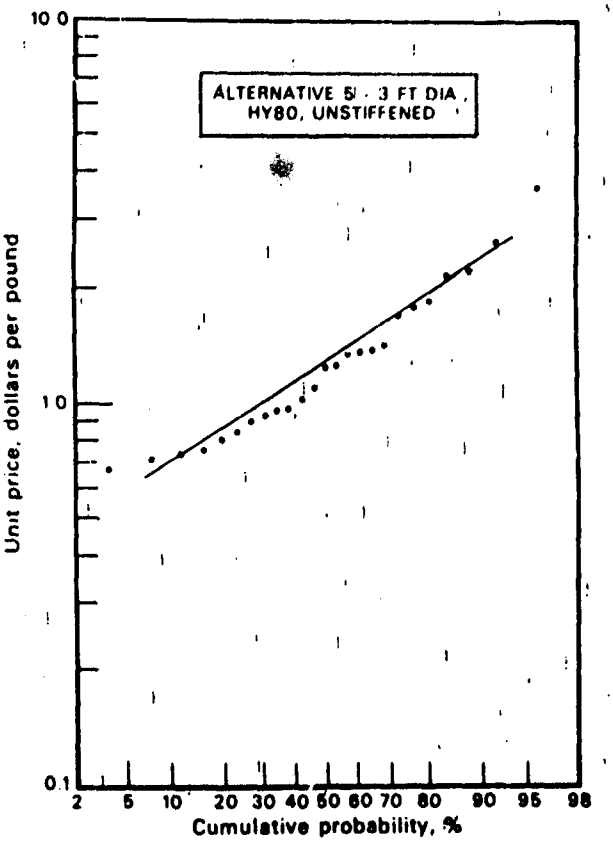

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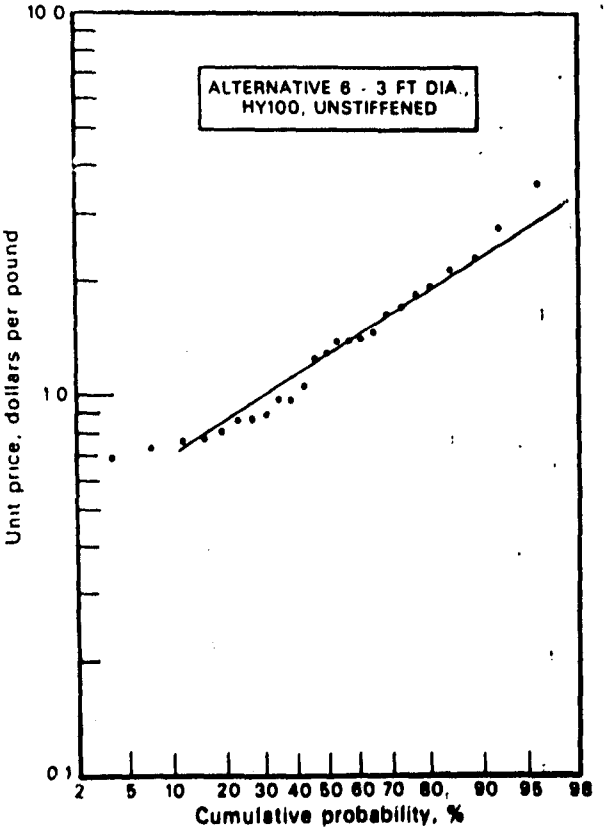

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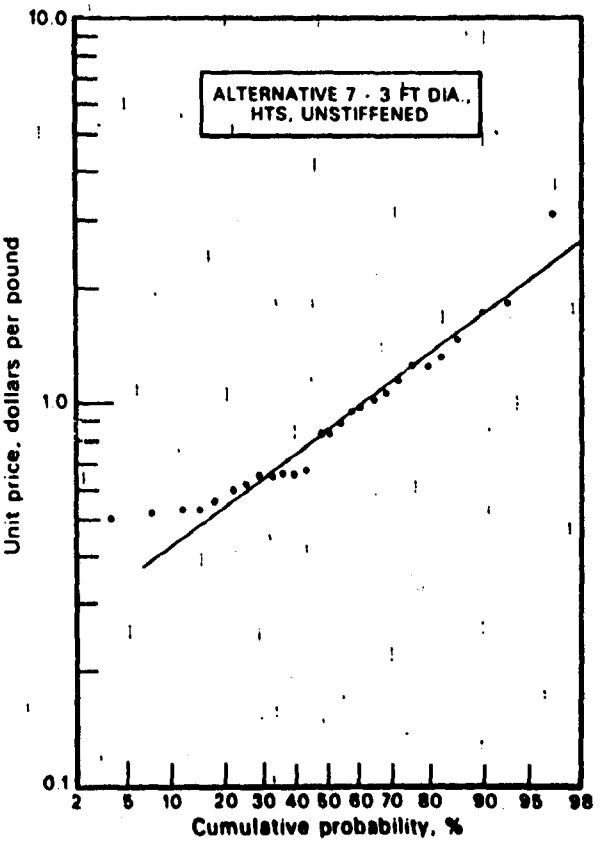

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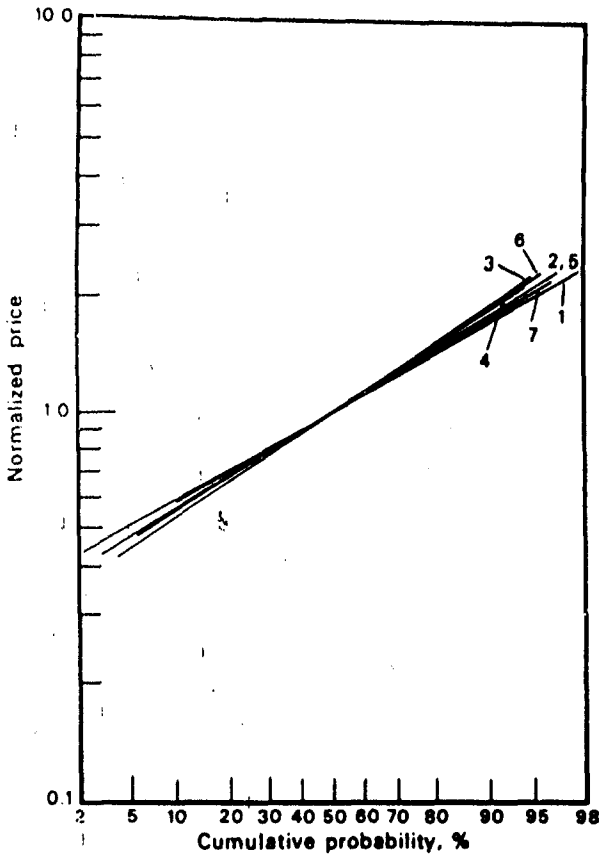

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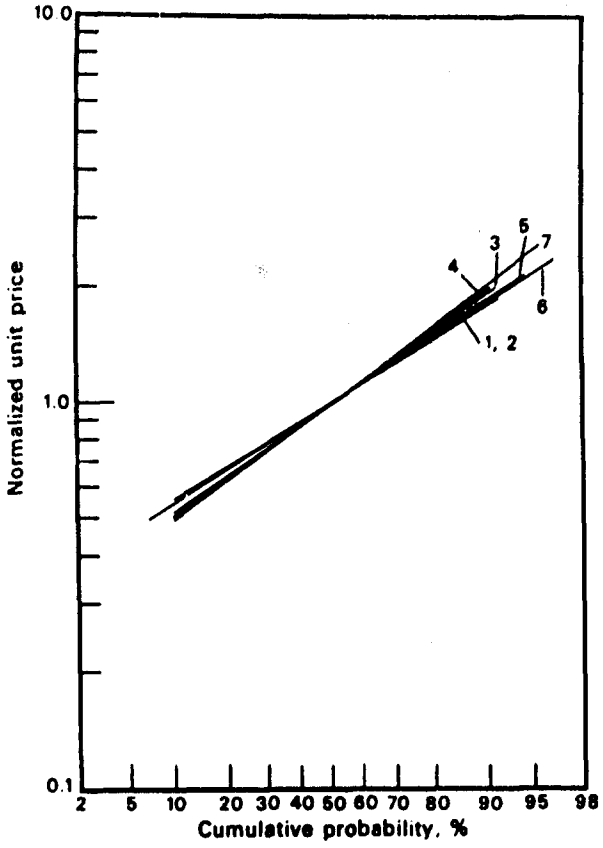

Figure 18

TABLE 3. SUMMARY OF ANALYSES

Unit price (dollars per pound)

Alternative	Mean and standard deviation of data sets	Mean of fitted log normal distribution
1	1,53 ; 0,92	1,32
2	1,60 ; 0,96	1,35
3	2,83 ; 2,64	2,16
4	2,78 ; 2,65	2,27
5	1,37 ; 0,68	1,29
6	1,42 ; 0,69	1,28
7	1,12 ; 0,71	0,91

Total price (thousands of dollars)

Alternative	Mean and standard deviation of data sets	Mean of fitted log normal distribution
1	95,1 ; 54,1	85,0
2	92,3 ; 52,7	83,0
3	44,9 ; 38,2	35,5
4	39,9 ; 28,3	33,5
5	43,7 ; 20,4	39,0
6	45,3 ; 20,7	40,5
7	38,5 ; 20,7	34,0

APPENDIX 1

UNIVERSITY OF CALIFORNIA, SAN DIEGO

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

MARINE PHYSICAL LABORATORY
SCRIPPS INSTITUTION OF OCEANOGRAPHY

SAN DIEGO, CALIFORNIA 92152

November 10, 1971

MPL File: 02-U-260

Attention: Sales Manager

Subject: Request for preliminary cost information and interest in bidding. Response requested by December 1, 1971

Gentlemen:

The Marine Physical Laboratory has initiated a research program that will require several cylinders capable of withstanding external sea pressure for equipment installation. In calendar year 1972, as the program develops, we expect to solicit fixed-price bids for construction of two 6-ft and two 3-ft cylinders of a finalized design. In order to establish a basis for selecting the material for construction of the cylinders, approximate cost figures are desired for several alternative cylinder configurations.

If your company would be interested in bidding on the construction of these cylinders after the final design is complete, we ask that you provide the laboratory with "ball park" cost estimates for the fabrication of a cylinder of each of the seven designs shown on the enclosed drawing. We are particularly interested in identifying relative differences in cost, considering both material costs and labor costs, between cylinders of different steel types and between stiffened and unstiffened cylinders.

All of those firms who respond with this preliminary cost information will be placed on the bidders' list for this procurement.

Sincerely,

Victor C. Anderson
Associate Director
Marine Physical Laboratory

HR/y
Encl: D-40-K6-1